# EERA Conference - Trondheim September 21st, 2016 **Next Generation European Transmission Networks**

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ENTSO-E R,D&I Planning WG Convenor



#### Flash info on ENTSO-E

From volountary category association to EC-mandated body

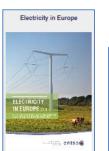


- Established and given legal mandates by the EU's Third Legislative Package in 2009
- **▶** Promotes and deploys close cooperation across Europe interconnected grids in:
  - **√** Planning
  - **✓** Operation
  - **✓** Market integration
  - **√** R&D coordination
  - √ Standards and statistics

Scenario Outlook & Adequacy Forecasts

10-YEAR RETWORK DEVELOPMENT PLAN 2015

ation





Statistical Factsheet



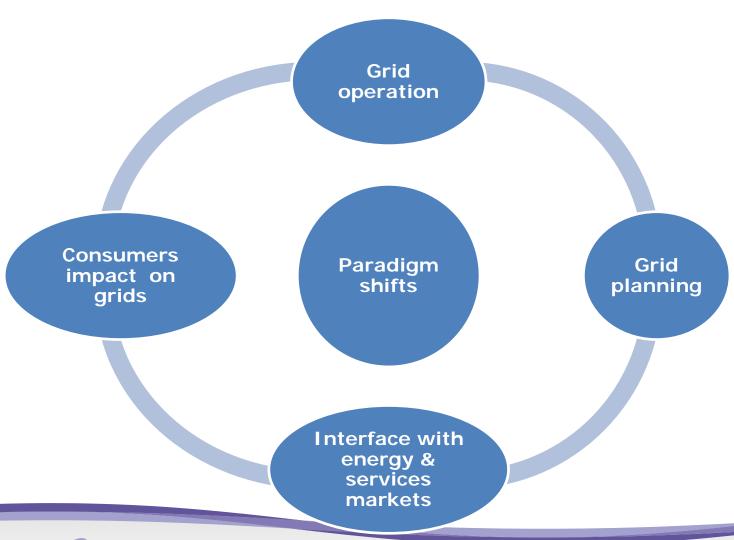
ENTSO-E members



- ➤ Key actor to build world's largest electricity market, to support EU energy& climate policies, which are deeply re-modelling the power system
- Focal point for technical, market and policy issues relating to European grids, interfacing with industry, system users, EU institutions, regulators



### Multiple challenges for transmission networks





### Multi-faceted paradigm shifts in power systems

### **Energy source mix**

- Electric sector is facing the major changes
- Electrification of transport, heat, processes
- Already here and now!



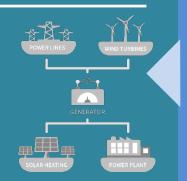
### Supergrids & microgrids

- Supergrids for wider areas systems optimization
- Microgrids for selfconsumption and local areas secondary optimisation
- Not mutually exclusive!



#### Consumers

- Grids and whole power systems - exist for them ...
- Passive and inelastic load idea is anachronistic in IoT era



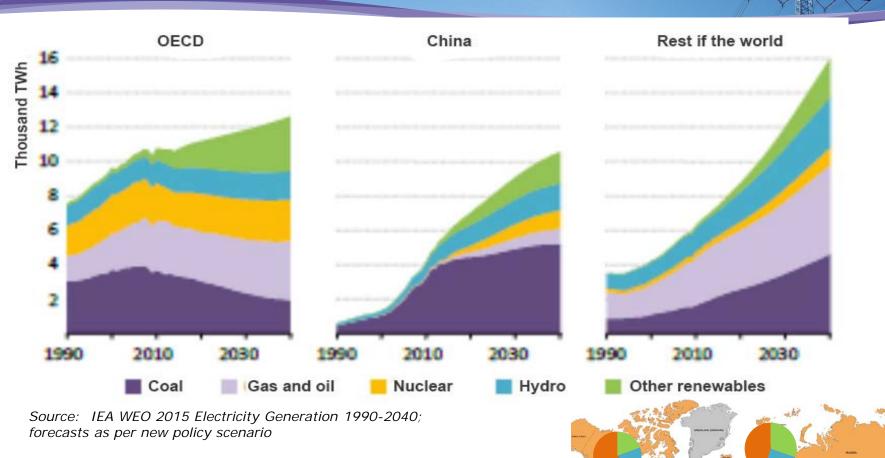
#### **Markets**

- Designed for competition among fossil fuel generation plants
- Now they strive to adapt to modified generation mix and to consumers empowerement





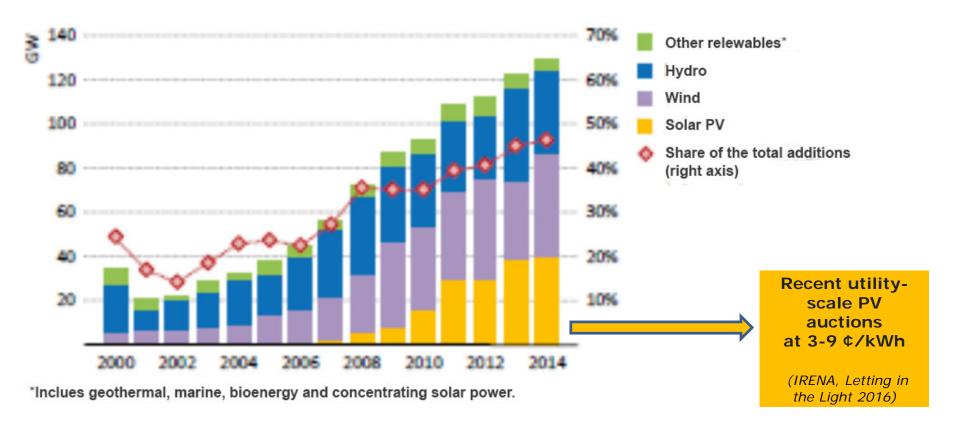
# Paradigm Shift: Climate Protection > Renewables/Distributed Generation



However, still long way to go; see current generation mix: renewable energy, nuclear and fossil fuels



# Half of capacity additions are renewables Worldwide trend, albeit for different reasons

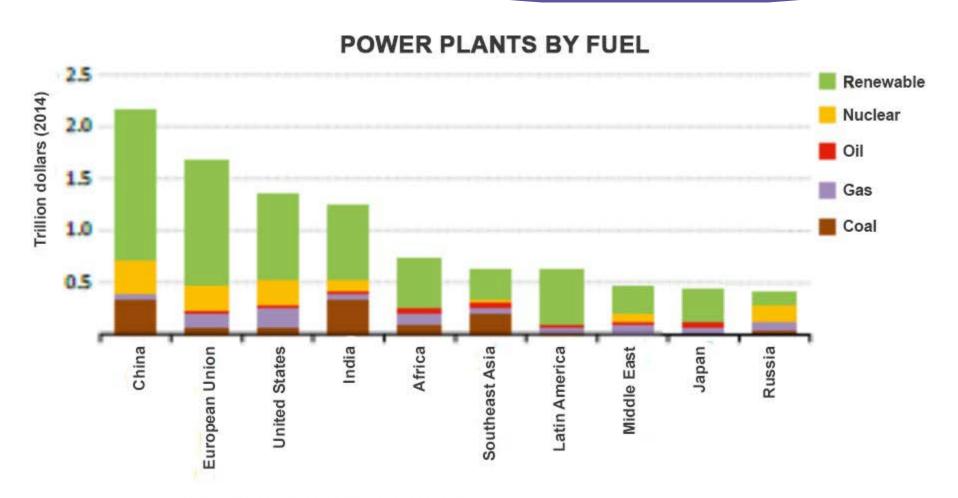


Global renewables-based power capacity additions by type and share of total capacity additions

Source: IEA, WEO 2015 Special Report Energy and Climate



# Money-wise, renewables dominate everywhere; investors & finance made clear choice



Cumulative investment in energy supply by selected region in the New Policies Scenario, 2015-2040

Source: IEA, WEO 2015 Special Report Energy and Climate



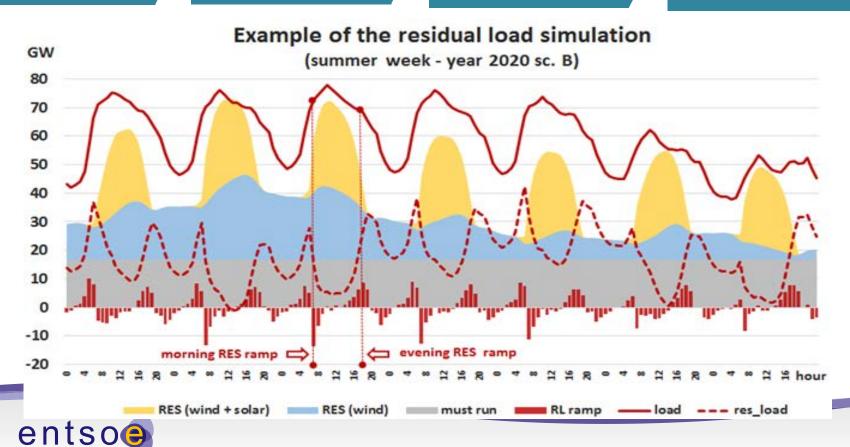
### The rest of the story is on grid operators' shoulders ...

Renewable electricity replaces fossil fuels

More efficient heating, transport, less CO<sub>2</sub>

Cheaper to decarbonize

Flexible tools needed because of RE fluctuations



# Limiting factors / challenges to overcome for higher variable renewable penetration

- Grid Codes for Increasing Operational Scheduling and Dispatch Challenges
  - ✓ Dispatch, ramping, reactive power, fault ride through capabilities of all plants
  - ✓ At high levels of RES ancillary services need to be provided by RES also
  - √ Needs credible grid code enforcement.
- Forecasting: Key requirement for all penetration levels for efficient system operation.
- ➤ Voltage Stability, Transient Stability, Inertia, and Fault Levels; where studied, present binding limiting factor for high penetrations of variable RES
- ➤ Network epansion and investments:
  - √ For medium and high levels of variable RES, additional grid infrastructure required
  - ✓ In Europe, 80% of 150 billion € transmission investment until 2030 is driven by RES
- ➤ Governance: Need for greater information sharing and transparency between systems.
- **➢**Other observations on ancillary services, storage, offshore wind, transients, markets



# Evolution of grid operation: smarter criteria, new tools, TSO-DSO cooperation

- ■Few TSOs rely on DSO information
  - **Storage**: short term and reserve markets



**Flexibility** 

- ■DR: 5% of the electricity demand
- Behind-meterPV affects system planning also

- **All** TSOs' grid & market tools rely on **data hubs** information ("distributed flexibility")
- Storage and DR: Europe wide for capacity and flexibility services



2020



2025



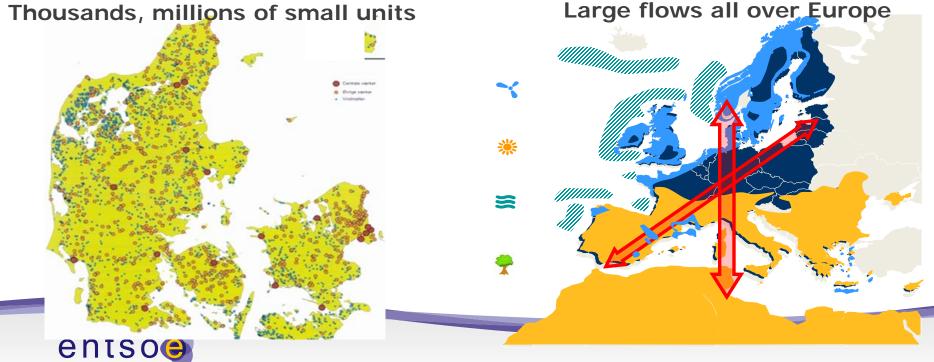
- New tools for regional security assessment (e.g. from iTesla, Umbrella, other EU projects)
- Limited interaction with other energy network
- Planning based on a modular methodology (eHighway2050)

- Interaction TSO security assessment data hubs
- EU wide coordinated planning based on overall energy system view



# Increased needs and scope for cooperation distribution – transmission

- > Fluctuating RES with low capacity factors need strong, continental size grids
- > Distributed generation needs smart grids
- **▶** Both need stronger cooperation transmission distribution
- > These needs appear wherever in the world the RE contribution grows
- ➤ Distribution reliability in much of the world needs to improve a lot smart grids and microgrids can help



### Areas for enhancing TSO/DSO cooperation



#### **MARKETS**

- Ensure consistency between wholesale and retail market
- Unlock DSR potential
- One single market



#### DATA

- Define data needs to fulfil regulated tasks
- Using existing standard developed at EU level (CIM format)
- · IT architecture for data management

### **OPERATIONS**



- Define needs around observability
- Active power mgt actions with impact on balancing + congestion in transmission should be overseen by TSOs
- Define roles of TSOs and DSOs

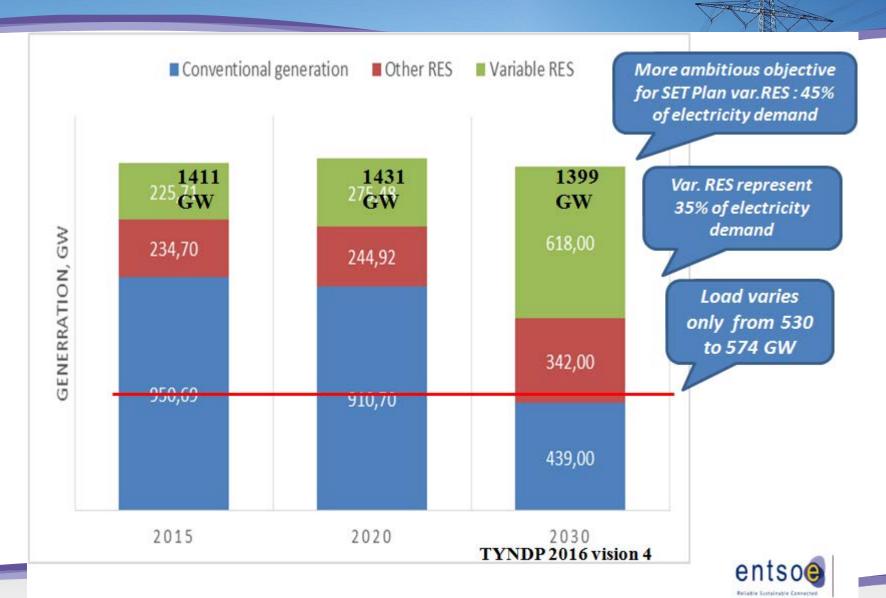
#### **PLANNING**



- Enhance the information exchange
- Coordination of the assessment of connection capacity
- Enhance resilience



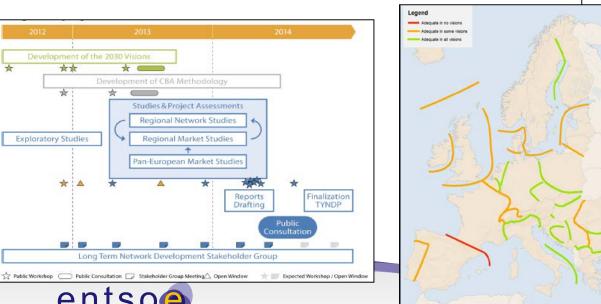
### The generation mix challenge in Europe





### Evolution of grid planning: from national to continental planning and beyond

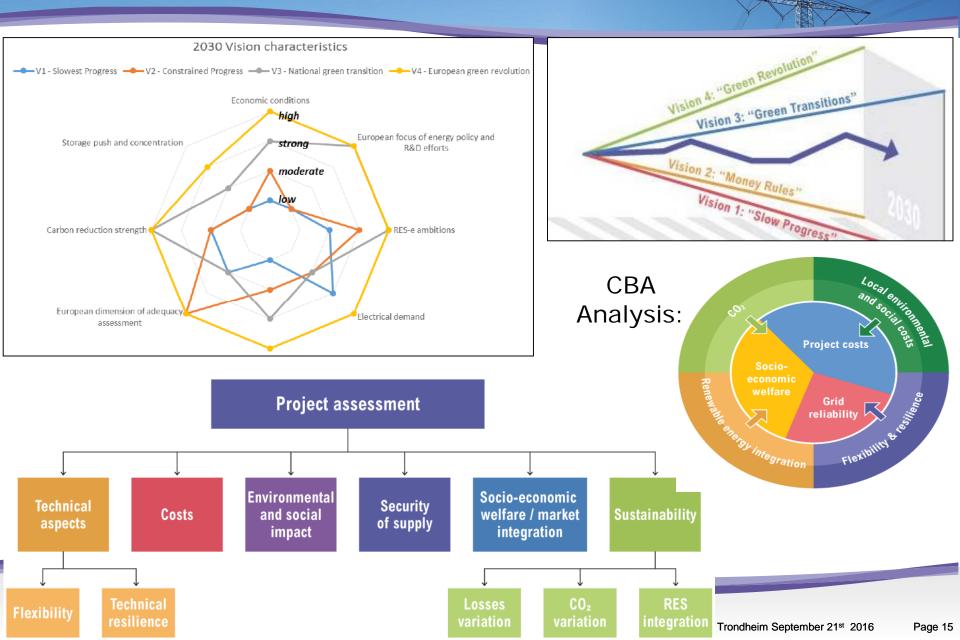
- > Since 2009 the European legislator has tasked ENTSO-E with the delivery of a European network development plan which builds on national plans and includes specific regional investment plans
- > Having a European approach to grid planning ensures consistency and cost-efficiency





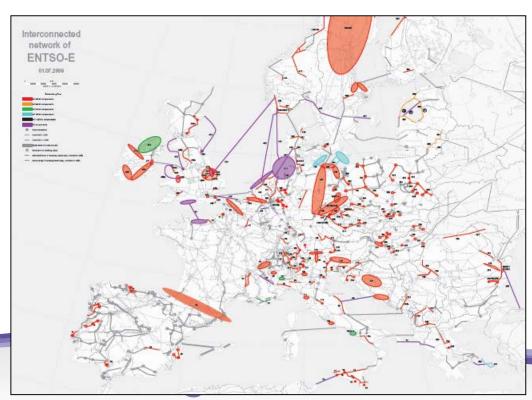
**Exploratory Studies** 

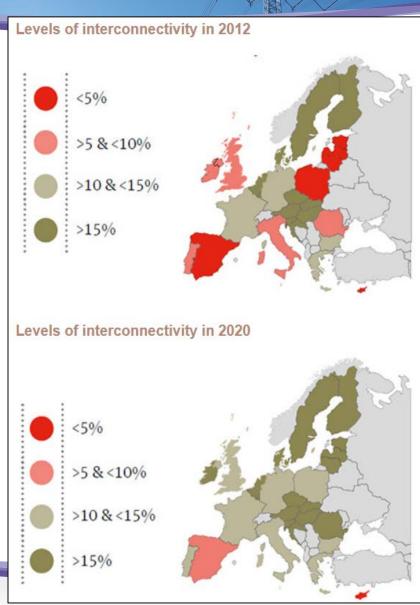
# Visions, scenarios, evaluation metrics, assessment methodologies



# Interconnections are one main focus of EU-wide infrastructures planning, and shall shape future grids

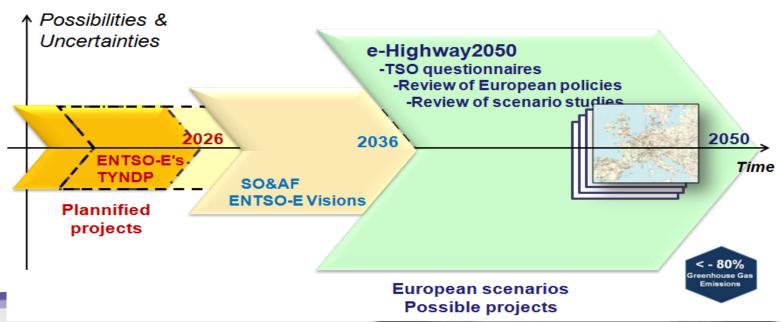
➤ The TEN-E Guidelines identify nine strategic geographic infrastructure priority corridors in the domains of electricity, gas and oil, and three EUwide infrastructure priority areas for electricity highways, smart grids and CO2 CCS





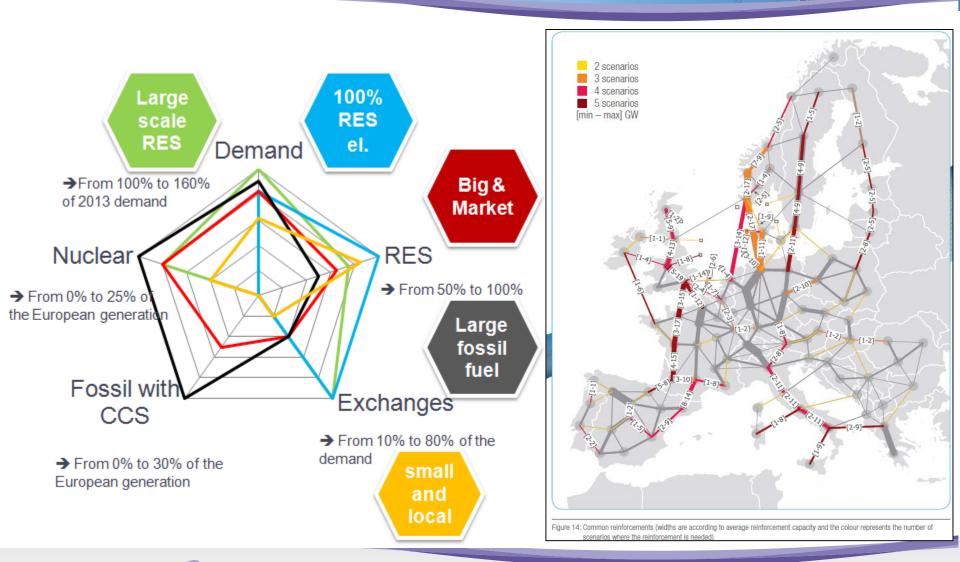
# Planning the next generation network: e-Highway project

- Wide range of options/scenario/sensitivities, for comprehensiveness of projections
- > No super-imposed DC supergrid has been applied
- Priority corridors common to several scenarios are no-regret investment reccomendations





# E-Highway scenarios and identified set of invariant grid expansions





# Evolution of grids to cope with market design, regulation and consumers' empowerement

#### Implementation of:

 Europe wide market coupling (CACM)

 Balancing network code as basis for DSR/DER

- Data privacy and security
- Providing data in time and form to those with need and authorisation



- DSR and DER are used for balancing and other markets
- Smart apps, data hubs, non-discriminatory access— well integrated with DSOs/TSOs' software
- Compliance with data protection regulation

2020 Innovation 2025

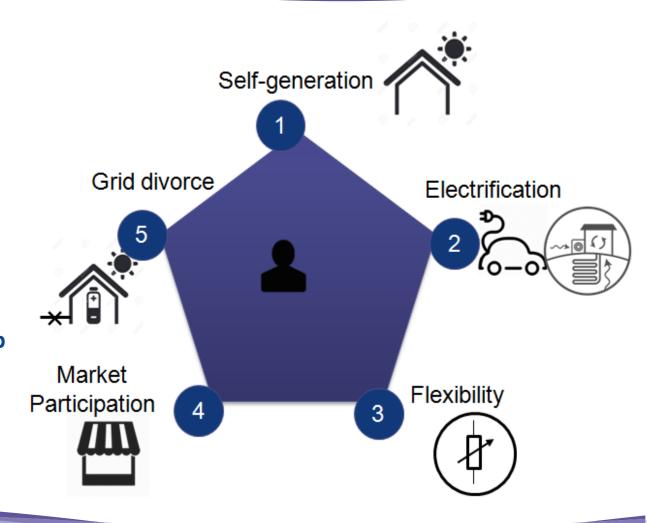
(Energy Cloud)





#### **Active end-users**

- ➤ With smart meters, homes, businesses and factories become a resource for the system
- ➤ With prosumers and active consumers, also grid reliability could become individualized
- ➤ Digitalisation of consumerside power system opens up pletora of services, both for end users benefit and for grid operation





# Topics for next 10 years innovation actions are identified in ENTSO-E R,D&I Roadmap, issued in July 2016

Clusters		Functional Objectives	FO contents
C1 Modernization of the Network	T1	Optimal grid design	Optimal grid design: planning, adequacy, tools
	T2	Smart Asset Management	Smart Asset Management; predictive and on-condition maintenance; capex optmisation
	T3	New materials & technologies	Use of new materials and power technologies; new construction and maintenenance methods
	T4	Environmental challenges & stakeholders	Environmental impact, public acceptance, stakeholders participation
C2 Security and System Stability	T5	Grid observability	Observability of the grid: PMUs, WAM, Sensors, DSO information exchange
	T6	Grid controllability	Controllability of the grid: frequency and voltage stability, power quality, synthetic inertia
	T7	Expert systems and tools	Decision support tools, automatic control and expert systems
	T8	Reliability and resilience	Reliability and resilience: defense and restauration plans, probabilistic approach, risk assessment, self healing
	T9	Enhanced ancillary services	Enhanced ancillary services for network operation; cross-border supply of services
C3	T10	Storage integration	Storage integration, definition and use of storage services; system added value from storage
	T11	Demand Response	Demand Response, tools to use DSR; Load profile, EV impact
Flexibility of	T12	RES forecast	Improved RES forecast and optimal capacity operation
Power System	T13	Flexible grid use	Flexible grid use: dynamic rating equipment, power electronic devices; use of interconnectors
	T14	Interaction with non electrical energy networks	Interaction/coordination with other energy networks (gas, heat, transport)
C4	T15	Market - grid integration	Integration of market and grid operation across timeframes (up to real time)
Economy & Efficiency of Power System	T16	Business models	Business models (for storage, grid extension, distributed generation) for optimal investments in the network
	T17	Flexible market design	Market design for adequacy, flexibility use, cross border exchanges, rationale use of RES, demand management
C5	T18	Big data management	Big data, data mining, data management
ICT &	T19	Standardization & data exchange	Standardization, protocols for communications and data exchange with DSOs and other grid operators
Digitalization of	T20	Internet of Things	New communication technologies, Internet of Things
Power System	T21	Cybersecurity	Cybersecurity

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C2	T6	Grid controllability	Controllability or and	Grid observability and			
Security and	T7	Expert systems and tools	Decision support tools, automatic contro	-			
System Stability	T8	Reliability and resilience	Reliability and resilience: defense and res	controllability			
	T9	Enhanced ancillary services	Enhanced ancillary services for network or	rv services for network operation; cross-border supply of services			
	T10	Storage integration	Storage integration, definition and use of	Adequacy, reliability, resilience			
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Economy &	T16	Business models	Business mouels from scores-70	Market and business mode	els		
Efficiency of Power System	T17	' Flexible market design	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	, cross border exchanges, rationale use of RES, demand management			
C5	T18	Big data management	Big data, data mining, data management	Dia Data LaT ICT application			
ICT &	T19	Standardization & data exchange	Standardization, protocols for communic	Big Data, IoT, ICT applicatio	ms		
Digitalization of	T20	Internet of Things	New communication technologies, Internet of Things				
Power System	T21	Cybersecurity	Cybersecurity				
	Antonio Iliceto - EERA General Assembly Trondheim September 22nd 2016 Page 22						

# **BACK-UPS**





# Future developments for the power system



Data hubs information: TSO/DSO grid & market tools





**Storage**: Services to TSOs/DSOs , prosumers

**Demand Response**: capacity, balancing services





**Distributed generation:** visibility and remote control and system services

**Electrical vehicles**: connections and deploying of charging points





**Security and stability:** New tools for regional security assessment and interaction with other energy networks

Energy system view: market, operation, planning



# Digitalisation of energy (ICT trends)



Hyper-Connectivity



Super-Computation



Cloud



IoT



Cyber-security

Manage the energy service from any device, anywhere Creates new channels from users to service providers Enabling communities in creating new energy services

Inferring relations between user-generated and other Information, beyond the capabilities today, as to improve existing or creating new energy services

Computation and data storage resources offered by 3<sup>rd</sup> parties as enabling platform for energy services

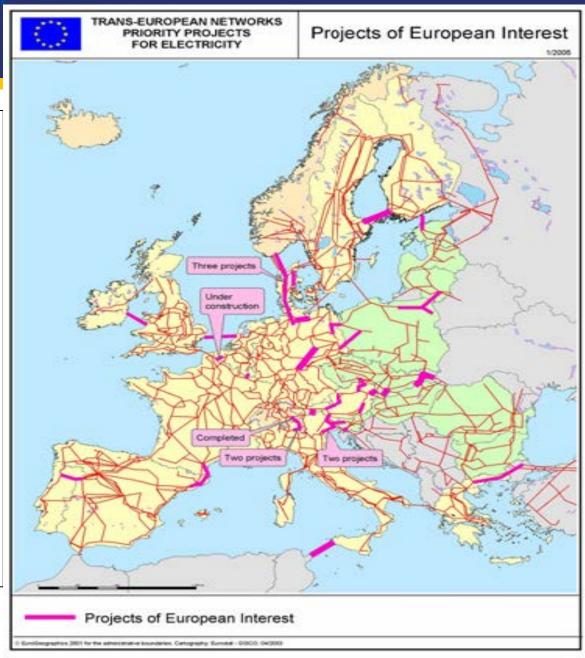
Pervasive access to a variety of sensing and control devices

Privacy, 3<sup>rd</sup> party access to user data only by consent. Protects energy system against failure from cyber attacks Projects of European Interest

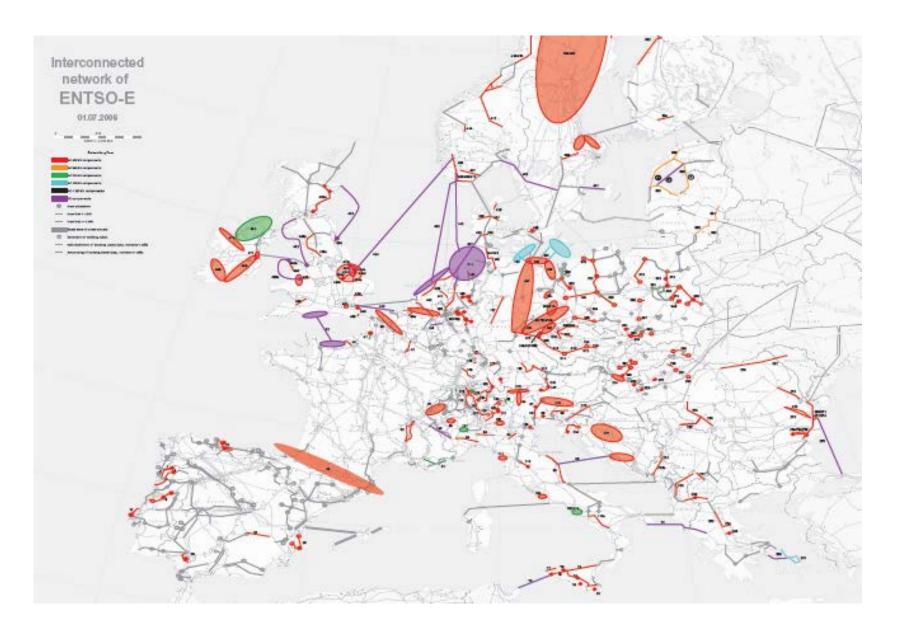
The projects of European interest are of utmost importance to achieve climate-energy policies objectives

#### **Projects may deal with:**

- Internal network reinforcements
- Interconnection within member states
- Interconnection with neighboring countries

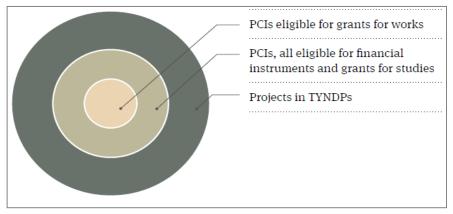


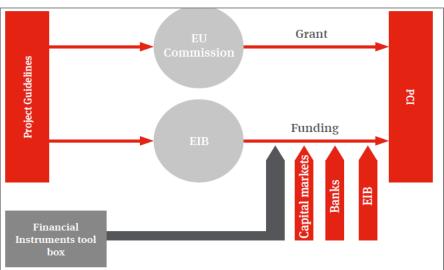
## Aree e corridoi da potenziare



### I corridioi prioritari

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#### **Electricity Priority Corridors**

Northern Seas offshore;

An integrated offshore electricity grid in the North Sea, the Irish Sea, the English Charmel, the Ballic Sea and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage.

Offshore connections will have to combine with interconnectors between countries to bring the generated electricity to shore, while reinforcements of the existing gold will be needed to treasent! electricity to the major energy consemption centres further inland and to storage capacities in the Alpa or Nordic countries.

North-Sou

tal transmiteton needs will arise to Wester pul renewable electricity generation will ustal rule

Strong richits by interconnections as well as interconnections with third countries will become increasingly important.

Strengthening the electricity network to ensure that reconstite energy grammind to the Korth can flow to a North America.

Description but become in

Auchipated interdiscent expotences 400 M.
Type of projects likely to used foresting upder the COP, projects that business security.

North-South electricity interconnections in Western Europe

Electricity interconnections between Member States and with the Mediterraneous, notably to connect energy islands and to integrate electricity from renewable sources.

The purpose of this priority is the integration of new capacities, mainly from researchies, in Western Europe and their transmission to consumption centres in other parts of the confinent. One central element will be to increase the internomentions between Member States in Western Europe, strengthening the electricity network to ensure that renewable energy generated in the North of this region can flow in a North-South direction. Another element will be to overcome bettlerecks and strengthen connections to allow the transmission of sensewable energy generation from the Berlan Perinnella to the rest of Europe across the Pyrenese.

North-South electricity interconnections in Central Eastern and South Eastern Europe

Electricity interconnections and internal lines in North-South and East-West directions to complete the internal market and integrate secessation from renewable enemy sources.

The purpose of this corridor will be to promote the integration of researchies energy accurace, improve regional market tringeration, increase the statility and predictability of supply and market arises a secure and reliable system. Building on exhiting political commitment and comperation in the region, for each will be to strengthen regional electricity to support an appropriate balancing system and to solve infrastructure page. Another challenge well be to develop adequate intercentrectors to the demand centres in Central-South and Southern Europea and to pumped a storage power placets,

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transfer the totagonities of economicle energy mores, improve regional market integration, necessare the stability and predictability of apply and maintain a secure and reliable

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Antistpaled broadment equipments

Type of projects that's to need through ing under the CEF-projects that to reserve unit if supply and address help three, energy

while also accommodating new generation in Eastern Europe.

Baltic Energy Market Interconnection Plan in electricity

Interconnections between Member States in the Baltic region and reinforcing internal grid infrastructures accordingly, to end isolation of the Baltic States and to finite market integration in the region.

This carridor will build on the well-established cooperation in this region in delivering the Baltic Energy Macket Interconnection Plan (BEMIP), a comprehensive action plan on energy interconnections and market improvement in the Baltic Sas Region. The main challenge is to connect the times Baltic Saste to neighbouring EU countries and to ensure proper functioning of the market by full implementation of the internal market rules. These are efforts to ensure that the Baltic States Join the Northic and the North Western protonal market rules.



Delivering the Salits Energy Market Intercented from Plan (1900.0°) Procured on taloguised gettle to Salite model militerant recurrency supply Salitte relative energy supply

team proper functioning of the market by all traptementation of the toleraid market size.

Auto qualed investment equipment

Type of projects likely to need financing under the CEP-projects that contribate in realing building and increase security of

#### Gas Priority Corridors

North-South gas interconnections in Western Europe

Gas intercorrections for North-South flows in Western Europe to further diversify routes and to increase short-term delivershillty.

The purpose of this corridor is to better interconnect the Mediterranean area, and therefore supplies from Africa and the Northern supply corridor, With supplies from Norway and Resala. Although some progress has been made in recent years, there is still a limited interconnection level to the liberian Perinaula, hindering the best use of the well-deweloped Berlar pay myout intestructure.



Parties directly routes and increase short

area, and thus supplies from Africa and the that here supply as etd.m, with supplies for there are not found.

Increase about term gas delivery

resource indexes a localization with the

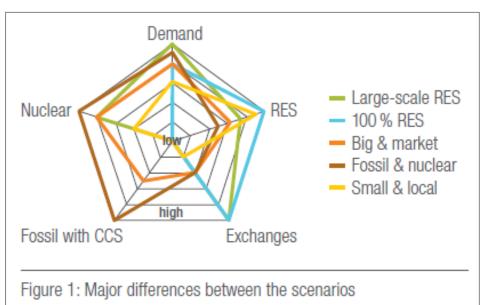
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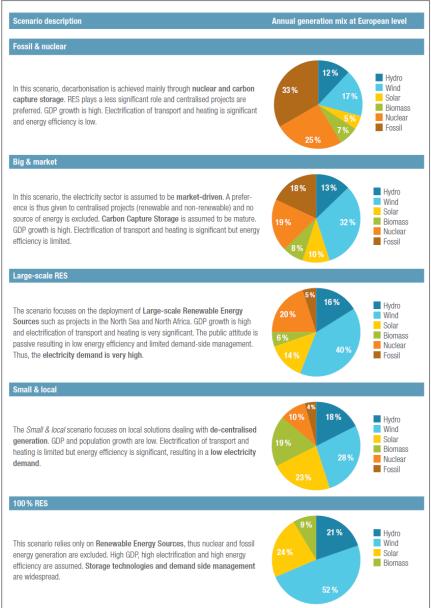
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Type of projects likely to need fluors under the CEF, projects that countly

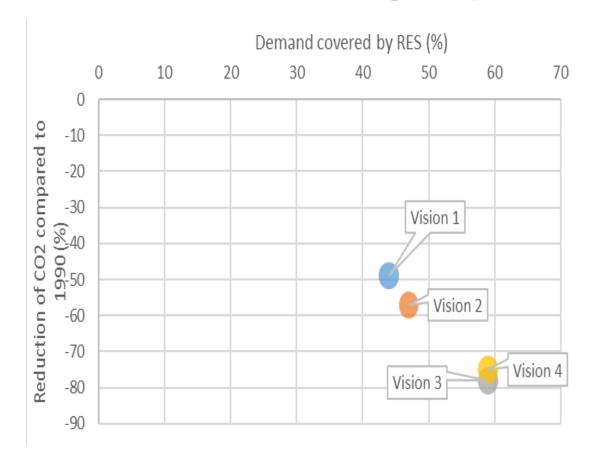
### Gli scenari di lungo periodo

- ➤ Individuati dal progetto europe e-Highway
- Rappresentano un ampio ventaglio di possibilità
- Lo scenario che si realizzerà sarà una combinazone lineare degli scenari-base





### TYNDP scenarios: a wide range of plausible futures

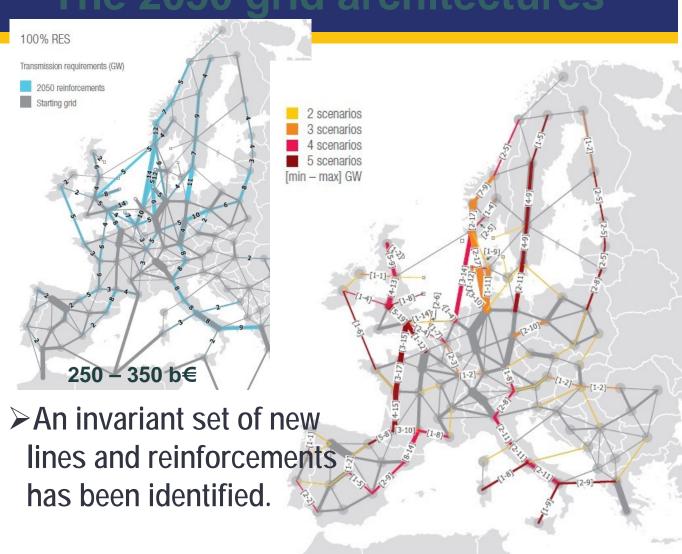


All 2030 Visions matching the renewables objectives of the electricity system.

(V1-2 and V3-4 show a strong differentiation in spatial distribution of generation)



# The 2050 grid architectures



100 - 400 b€



# **User Impact on System Operators**

	Revenue Model	User value proposition	Operations
Self-generation	declining revenue from energy based distribution tariffs	storage capabilities	Technical statuary limit and PQ violations
Electrification	increased revenue from load growth	enabling platform for e- mobility charging	network expansion and congestion management
Flexibility	alternative for procurement of system services (TSO)	Facilitating user flexibility and markets (load mgnt, generation mgnt, accounting)	use customer flexibility for operations and asset optimization
<b>Market</b> participation	new value network requiring new business processes	Dynamic pricing, connection management and accounting	TSOs/DSOs cooperation
Grid divorce	hedging /lost customer	Dynamic pricing/re- connection management, maintenance/emergency power	?

#### **ENTSO-E** activities on R&D and Innovation

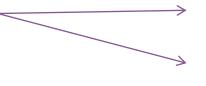
Strategy 2016 and change of name



- > R&D more and more necesary to cope with system paradigm shift
- ➤ Research, Development & Innovation Committee (RDIC) aims at coordinating actions and projects of TSOs, notably towards smarter grids, maximising added value between national and international level
- ➤ Main deliverables are built combining top-down and bottom-up approaches , plus extensive stakeholders consultation



**▶**2 main pillars:



Incubator of consortia for answering EC calls, together with research institutes and other stakeholders

Inter-TSO cooperation on best practices, knowledge sharing, addressing short-term challenges not covered by large programs

3 dimensions addressed:

Technology

**Processes** 

**Business models** 

>Active participation in the European energy research structures and platforms (now ETIP)



### Overview and interplay of ENTSO-E R&D mandated deliverables on R,D&I

**ENTSO-E Publications** 

2012

2013

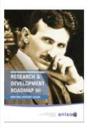
2014

2015

2016

2017

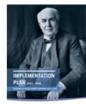
R&D Roadmap



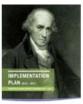
Sets a framework for medium and long term with defined targets

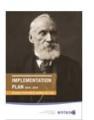
Implementation













Lists projects and actions for next 3 years (yearly update)







Assesses progress, gaps and deployment of R&D activities (yearly update)



### Role of grids in R&D processes



#### Pivotal role of grids:

- **✓** Backbone of the whole power system
- ✓ Indispensable enabler to low-carbon-systems → increased need of power transfer for RES generation optimisation
- √ Traditionally a centre of technical excellence and prone to continuos learning & improvement
- **▶** Role of grid operators for deployment of R&D results:
  - ✓ Although not primary R&D institutions, they own and manage the assets and systems where most innovation has to be deployed or connected
  - √ Only and obligated location for projects at demo stage
  - ✓ Natural interface and data provider towards both traditional actors (DSOs, power market players, equipment manufacturers, research institutes, univeristies) and also newcomers (storage operators, aggregators, balance services providers, service companies, ITC apps providers, etc.)
  - ✓ In charge of introducing and integrating under optimal system view several proposed new technologies and solutions

Grid operators should have a key involvment in early stage of R&D concepts to ensure proper system perspective, integration aspects, operator's requirements



### Grids and ENTSO-E role in European R&D arena

#### **►** Main overarching trends:

- ✓ Integration of different energy systems: gas, heating, transport, but also ICT, new materials
- ✓ Challenges and solutions tend to stretch over borders, hence higher level view is needed
- ✓ Strong political pressure towards innovation and smart grids/cities to maintain European competitive advantage on relevant technologies
- ✓ EU and all grid users expect ENTSO-E and other actors to anticipate the challenges, to timely identify and deploy cost-effective solutions in order to consolidate the European front-runner role on energy&climate issues
- ✓ Still various R&D activities related to grids are performed by several stakeholders, often with little coordination



TSOs mandated to coordinate efforts, to share priorities, to avoid overlaps, to achieve more-value-for-investment

Both among them and vs the Research Community



# **Current TSO involvement in EU projects**

23 European funded R&D projects

Active participation of 25 out of 41 TSOs from ENTSO-E

